

hep-ex/0607041  
SLAC-PUB-11856  
*BABAR*-TALK-05/113  
July 2006

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Johannes M. Bauer  
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Rare  $B$  decays permit stringent tests of the Standard Model and allow searches for new physics. Several rare radiative-decay studies of the  $B$  meson from the *BABAR* collaboration are described. So far no sign for new physics was discovered.

Submitted to the Conference Proceedings of the Fourth International  
Conference on Frontier Science — New Frontiers in Subnuclear Physics,  
September 12–17, 2005, Milan, Italy

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*Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309*

Work supported in part by Department of Energy contract  
DE-AC03-76SF00515.

## Rare Decays and Search for New Physics with *BABAR*

Johannes M. Bauer  
*University of Mississippi, University, MS 38677, U.S.A.*  
for the *BABAR* Collaboration

### Abstract

Rare  $B$  decays permit stringent tests of the Standard Model and allow searches for new physics. Several rare radiative-decay studies of the  $B$  meson from the *BABAR* collaboration are described. So far no sign for new physics was discovered.

### 1 Introduction

At the SLAC PEP-II  $B$ -Factory, the *BABAR* detector collected so far more than 250M  $B\bar{B}$  pairs, created by  $e^+e^-$  collisions at the  $\Upsilon(4S)$  resonance. This data set makes searches for rare decays feasible at branching fractions (BF) of  $10^{-4}$  or less. This talk concentrates on radiative  $B$  decays. Additional results from *BABAR* were discussed elsewhere at this conference. <sup>1)</sup>

## 2 Fully- and Semi-inclusive $B \rightarrow X_s \gamma$ , $B \rightarrow K^*(892)\gamma$ & $B \rightarrow K_2^*(1430)\gamma$

The lowest-order Feynman diagram of  $b \rightarrow s\gamma$  is a one-loop electromagnetic penguin, in which non-Standard Model (non-SM) virtual particles (like the Higgs) might influence the decay rate. Measuring the energy distribution of the  $b$  quark inside the  $B$  meson helps extract  $|V_{ub}|$  from  $B \rightarrow X_u l \nu$ . The decay  $b \rightarrow s\gamma$  was studied in inclusive and exclusive modes using  $\sim 89\text{M } B\bar{B}$  pairs.

In the so-called “fully-inclusive” measurement only the photon of  $B \rightarrow X_s \gamma$  needs to be detected, but large background has to be suppressed. In the “semi-inclusive” measurement, the  $B \rightarrow X_s \gamma$  BF is determined from 38 exclusive states with about 45% of the total rate estimated to be missing.

The  $E_\gamma$  spectra from the two  $B \rightarrow X_s \gamma$  analyses are shown in Fig.1. The  $K^*\gamma$  peak, prominent at high  $E_\gamma$  for the semi-inclusive analysis, is not visible for the inclusive analysis due to resolution constraints. Fig.2 left plots the fully-inclusive partial BFs against the value of the lower cut in  $E_\gamma$ . The overall semi-inclusive BF, when extrapolated to  $E_\gamma > 1.6\text{ GeV}$ , agrees with the SM prediction and with the results from other experiments (Fig.2 right). 2, 3)

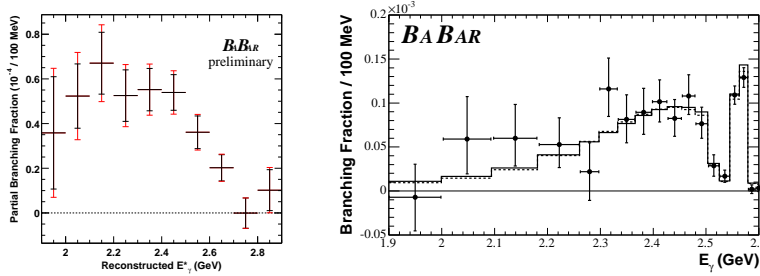


Figure 1: Photon energy spectrum from fully- (left, in  $\Upsilon(4S)$  frame) and semi-inclusive  $B \rightarrow X_s \gamma$  analyses (right, in  $B$  frame, with theory spectra overlaid).

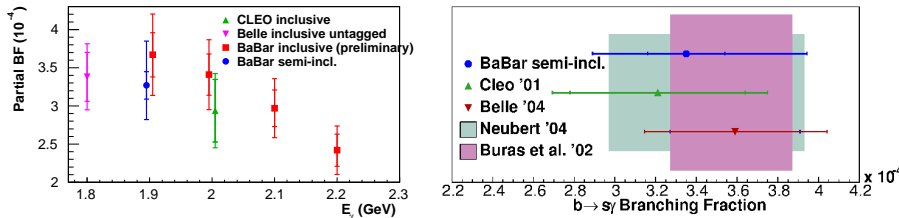


Figure 2: Partial BFs versus lower cut in  $E_\gamma$  (left) and overall BF measurements (right) of  $B \rightarrow X_s \gamma$  for  $E_\gamma > 1.6\text{ GeV}$ .

Non-perturbative hadronic effects complicate the theoretical calculations of exclusive decays like  $B \rightarrow K^*(892)\gamma$  and  $B \rightarrow K_2^*(1430)\gamma$ , so that the measurements are currently more accurate than the predictions. A summary of the results is shown in Fig.3. <sup>4, 5)</sup>

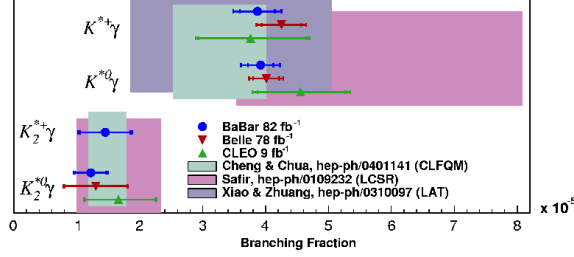


Figure 3: *Branching fractions of  $B \rightarrow K^*(892)\gamma$  and  $B \rightarrow K_2^*(1430)\gamma$ .*

### 3 $B \rightarrow X_s ll$ , $B \rightarrow K^{(*)} ll$ and $B \rightarrow (\rho, \omega)\gamma$

The decay  $b \rightarrow s ll$  has been measured semi-inclusively ( $B \rightarrow X_s ll$ ) on 89M  $B\bar{B}$  pairs, and exclusively ( $B \rightarrow K^{(*)} ll$ ) on 229M  $B\bar{B}$  pairs. The former measurement is again based on a sum of exclusive states, with about half of the total rate missing, and its BF <sup>6)</sup> of  $(5.6 \pm 1.5 \pm 0.6 \pm 1.1) \times 10^{-6}$  for  $m_{ll} > 0.2 \text{ GeV}/c^2$  agrees well with the SM prediction. The exclusive decay results are shown in Fig.4 left. <sup>7)</sup>

The decay  $b \rightarrow d\gamma$  has been studied in 221M  $B\bar{B}$  pairs by searching for  $B \rightarrow (\rho, \omega)\gamma$ . These decays go primarily through penguin diagrams, but also through  $W$ -exchange or  $W$ -annihilation. The background originates mainly from  $q\bar{q}$  ( $=u\bar{d}sc$ ) events. The BF results are summarized in Fig.4 right. <sup>8)</sup>

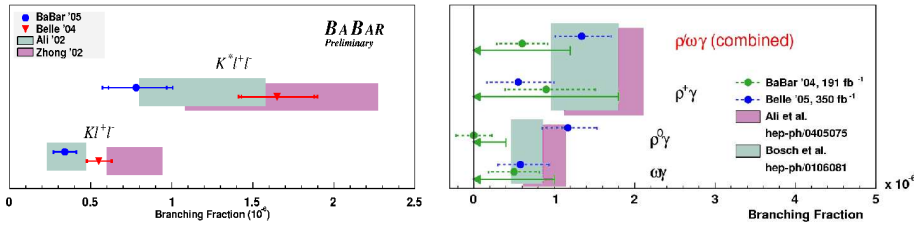


Figure 4: *BF measurements and SM predictions for  $K^{(*)} ll$  (left) and  $B \rightarrow (\rho, \omega)\gamma$  decays (right).*

#### 4 $\bar{B}^0 \rightarrow D^{*0}\gamma$ and $B^0 \rightarrow \phi\gamma$

The  $\bar{B}^0 \rightarrow D^{*0}\gamma$  decay with SM predictions around  $10^{-6}$  is dominated by  $W$ -exchange. The final  $B$  candidates from 88M  $B\bar{B}$  pairs are described by  $m_{\text{ES}} = \sqrt{E_{\text{beam}}^{*2} - p_B^{*2}}$  and  $\Delta E^* = E_B^* - E_{\text{beam}}^*$ , with  $E_{\text{beam}}^*$  being the center-of-mass (CM) beam energy, and  $E_B^*$  and  $p_B^{*2}$  the  $B$  candidate's CM energy and momentum. Background, mainly from  $B\bar{B}$  decays, is estimated to be  $9.4 \pm 1.7$  events in the  $m_{\text{ES}}\text{-}\Delta E$  signal box. Thirteen observed data events (Fig.5 left) lead to a BF upper limit of  $2.5 \times 10^{-5}$  at 90% confidence level (CL).<sup>9)</sup>

The experimental signature of the  $B^0 \rightarrow \phi\gamma$  decay is clean, but the SM prediction of the BF is very low with  $3.6 \times 10^{-12}$ . Candidates are selected from 124M  $B\bar{B}$  pairs. In the signal region, a  $q\bar{q}$  ( $B\bar{B}$ ) background of  $6.0 \pm 1.0$  ( $<0.1$ ) events is expected. Eight events observed in data (Fig.5 right) result in a BF upper limit of  $8.5 \times 10^{-7}$  at 90% CL.<sup>10)</sup>

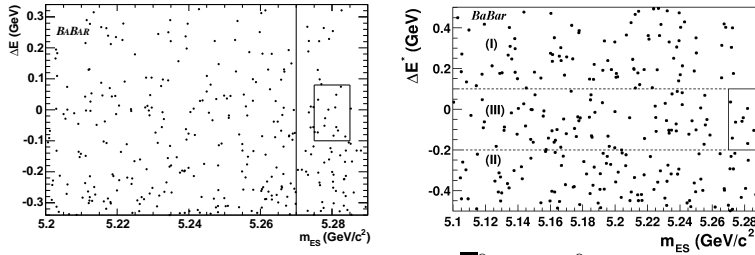


Figure 5:  $m_{\text{ES}}\text{-}\Delta E$  plane of real data for  $\bar{B}^0 \rightarrow D^{*0}\gamma$  (left) and  $B^0 \rightarrow \phi\gamma$  (right). In both plots the signal box is indicated on the right side.

The author thanks the BABAR collaboration, the SLAC accelerator group and all contributing computing organizations. He was supported by U.S. Department of Energy grant DE-FG05-91ER40622.

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